Ames Research Center

2009 Robotic Recon Experiment

Desert RATS at Black Point Lava Flow, Arizona

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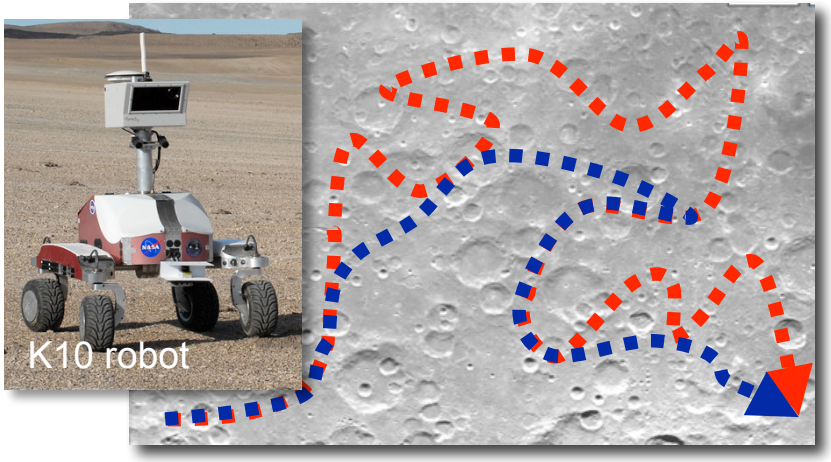
2009 Robotic Recon Experiment

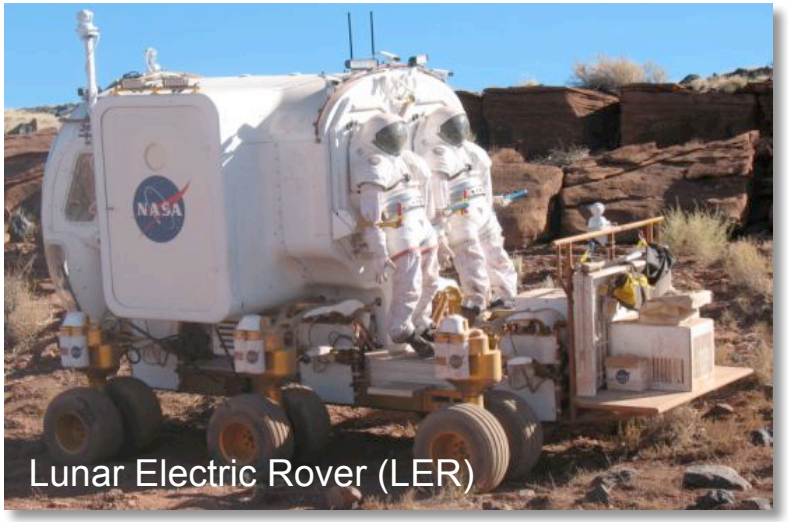
Objectives

- Test robotic recon in advance of crew (LER-based mission)
- Test coordinated human-robot field exploration technique
- Fold lessons learned into lunar surface science ops concepts



Expected outcomes

- Capture requirements (instruments, comm, nav, etc.) for robotic recon
- Assess impact of robotic recon on traverse planning & crew productivity
- Improve productivity & science return of human exploration missions



Funded by: ***ESMD ETDP Human-Robotic Systems***
ESMD DIO Analogs Program

ESMD Analogs: Science FOR the Moon

June	July	2009 Aug	Sept	Oct	2010 Feb
					
Desert RATS	**Pavilion Lake**	**Haughton Mars**	**Desert RATS**	**NEEMO**	**Surface Ops**
Robotic Recon Test	**Science Operations Development**	**Science Operations**	**Pressurized Rover & Tri-ATHLETE Tests**	**Engineering & Science Operations**	**ISRU Testing**

Astronaut Training Activities

www.nasa.gov/exploration/analogs

YouTube NASA**analog**TV

2009 Robotic Recon Experiment

Robotics for Human Exploration

- Study impact on traverse planning
  - Reduce uncertainty
  - Improve science merit
- Study impact on crew productivity
  - Improve task efficiency
  - Improve data collection quality

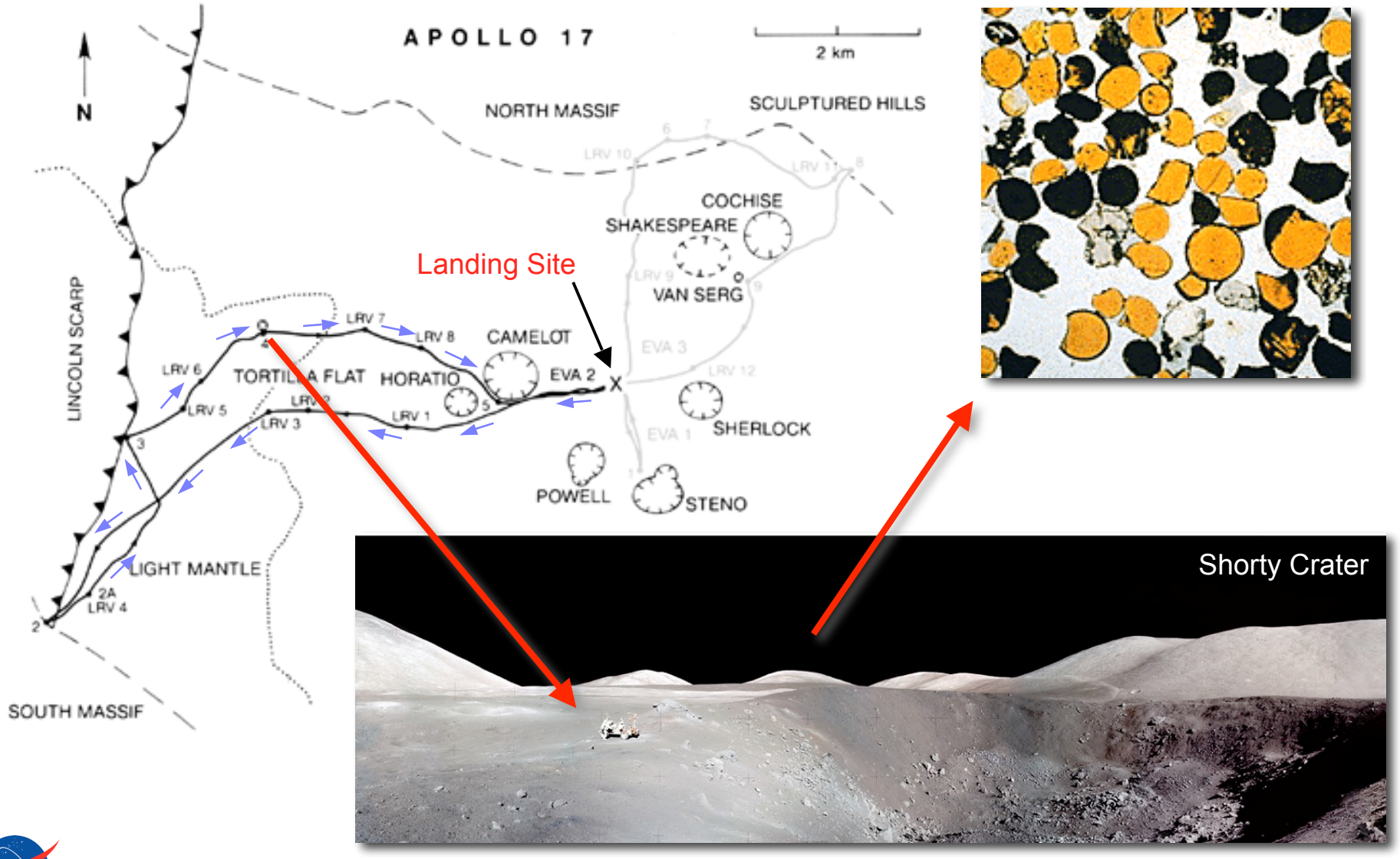

Black Point Lava Flow

Highlights

- **Pre-recon**: Plan two crew traverses (1-day) with orbital data
- **Robotic recon mission**: K10 robot with science instruments
- **Pre-crew**: Revise traverses using surface data collected by K10
- **Crew mission**: LER comparison of traverses with/without recon data

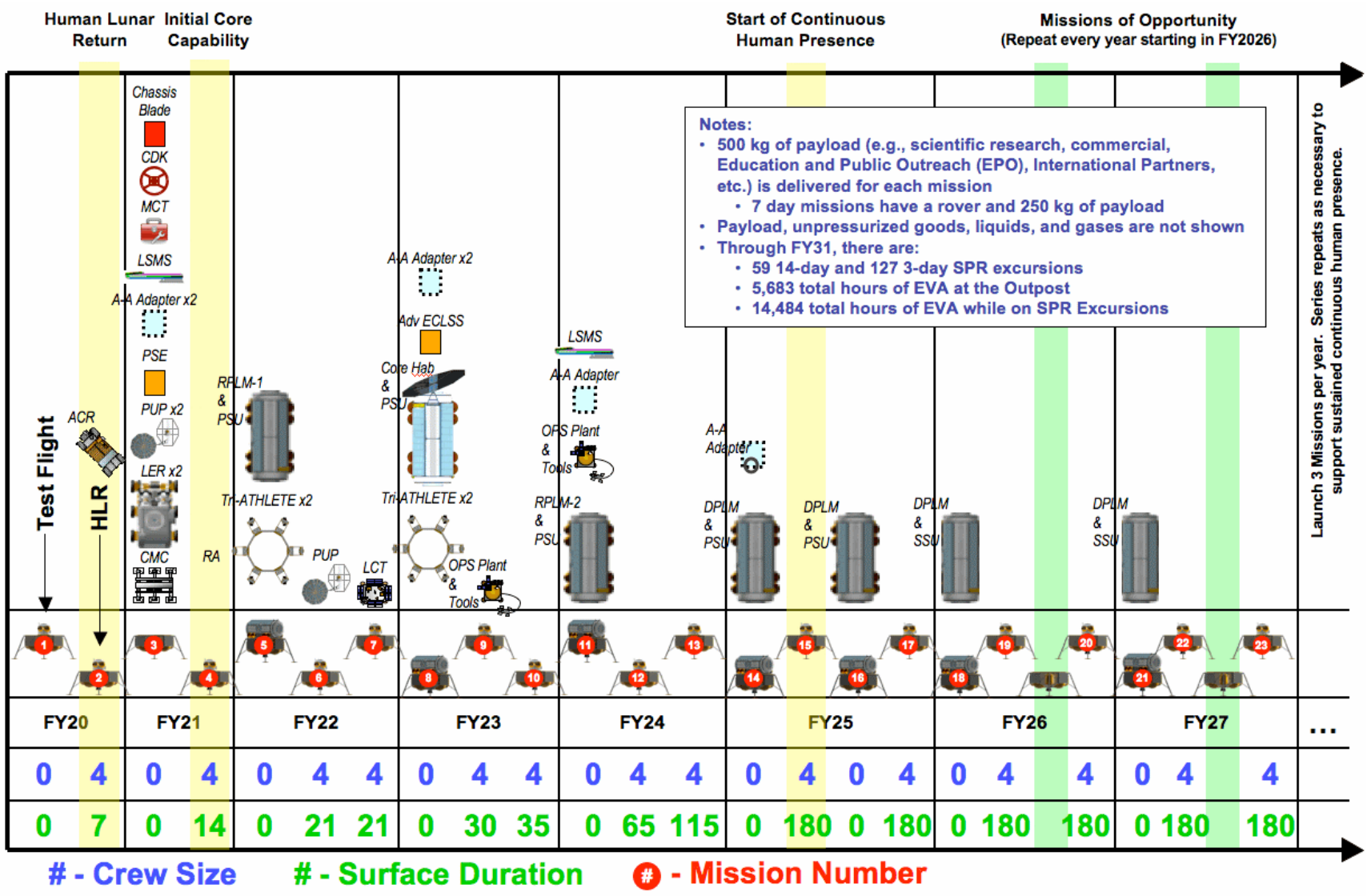
http://lunarscience.nasa.gov/roboticrecon

Why is Recon Useful?

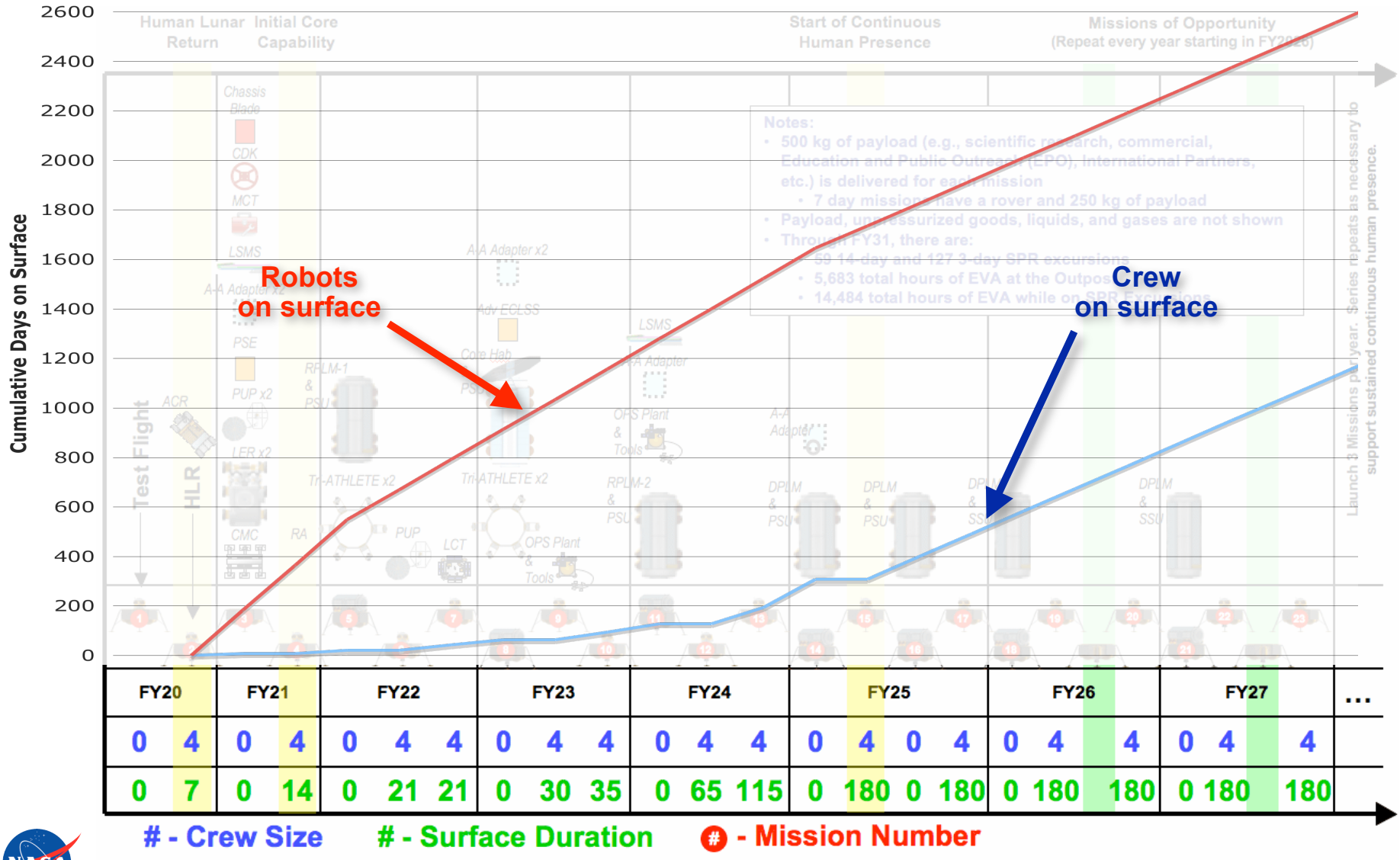


Why is Recon Useful?

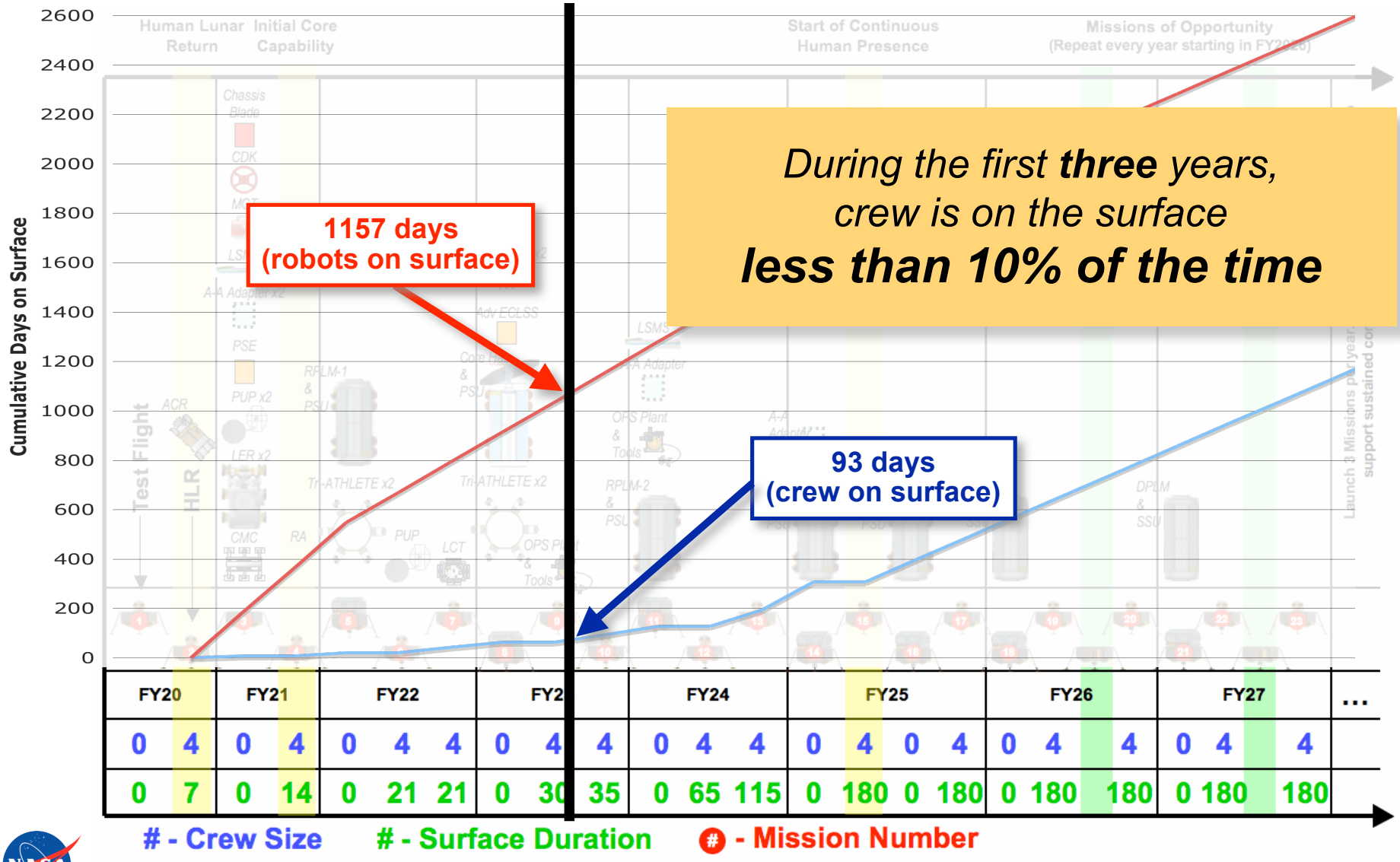
Lunar Architecture Manifest (Scenario 4.3.2, April 2009)



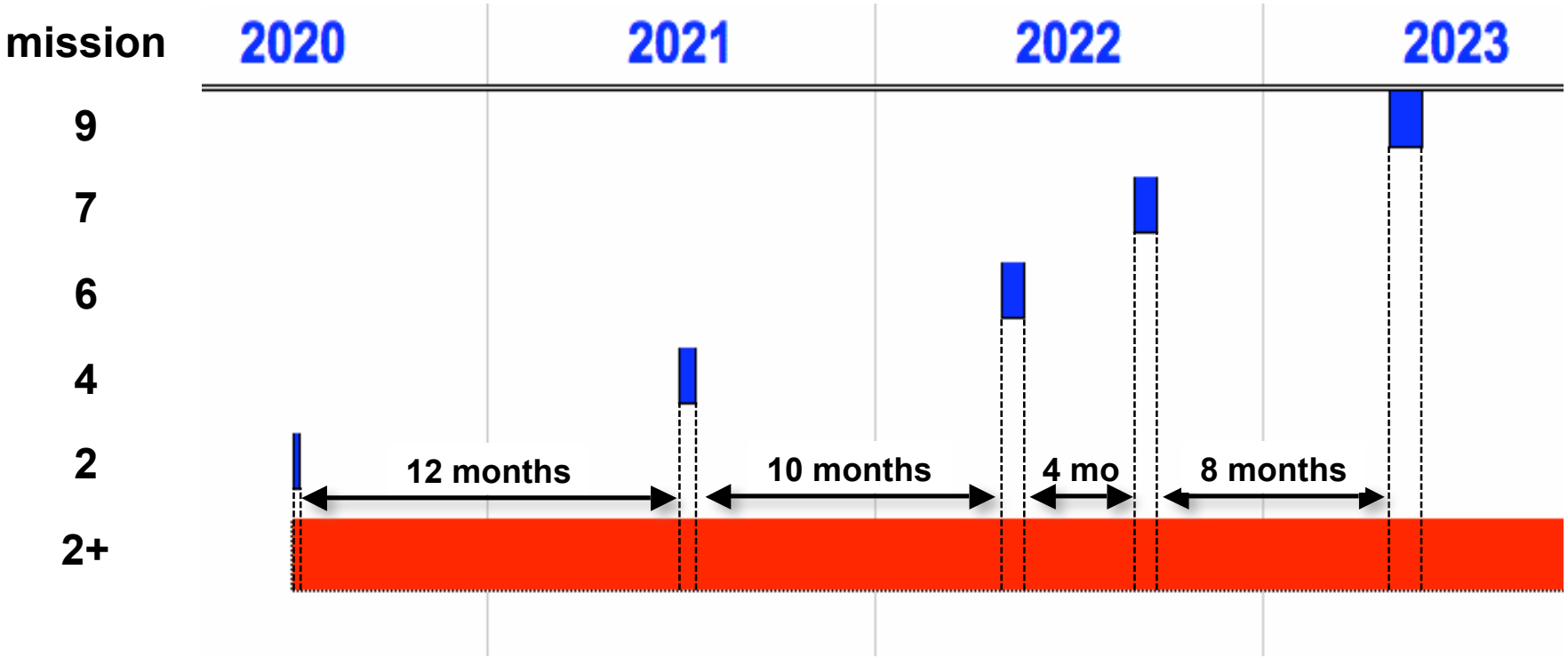
Notional Lunar Campaign



First Three Years



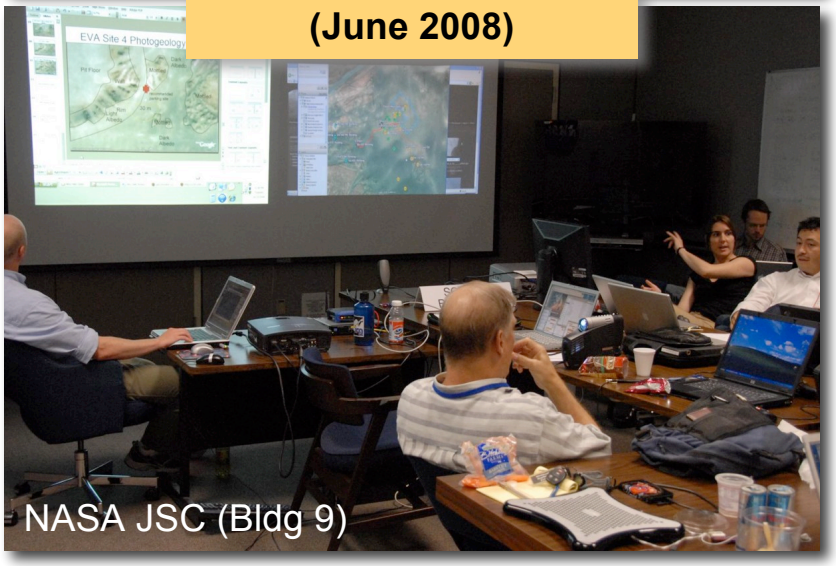
First Three Years

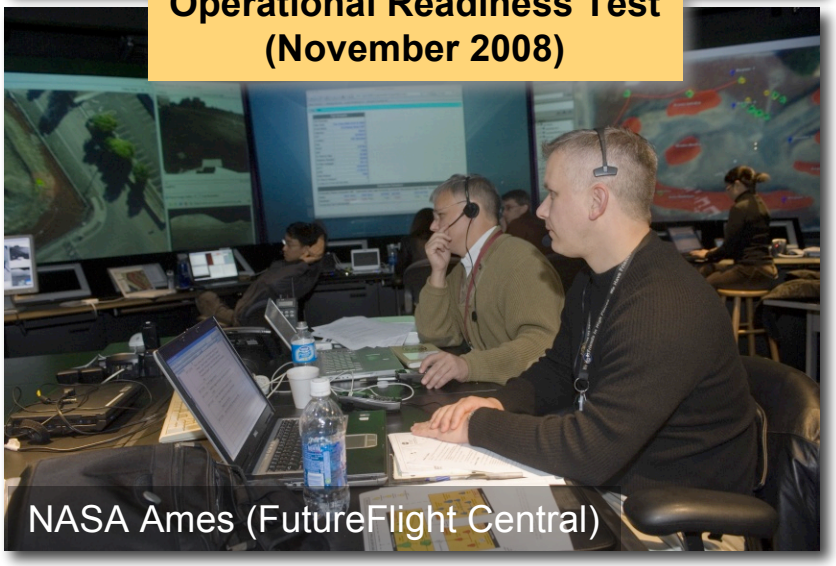


Robotic Recon Development (2008)

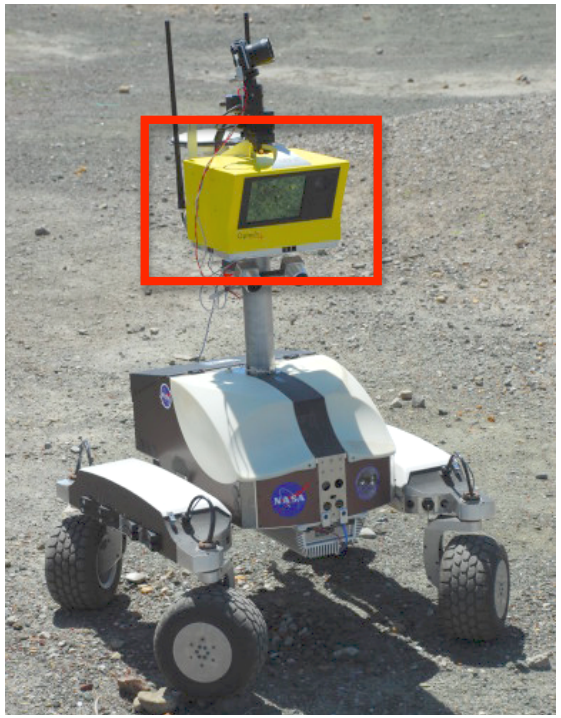
Desert RATS Field Test (June 2008)

Robotic Recon Operational Readiness Test (November 2008)



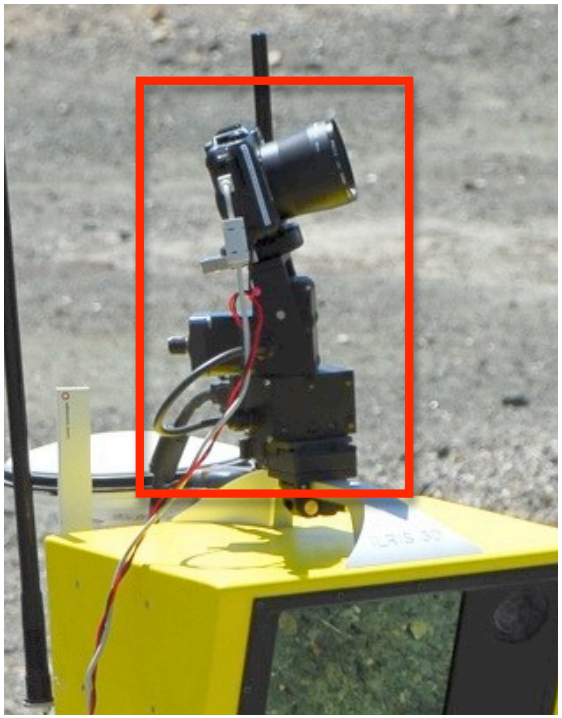


Robotic Recon Instruments



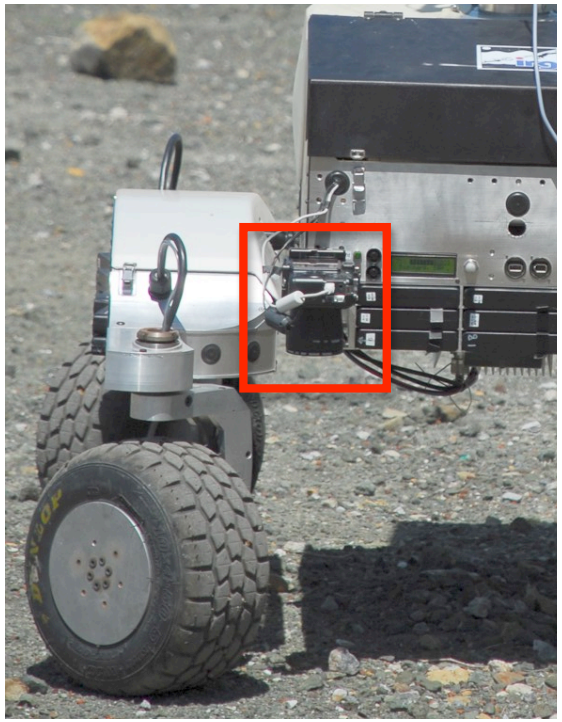
3D scanning LIDAR

- 3D topography measurements
- 5mm @ 500m
- >2x resolution of LRO LOLA



GigaPan

- Oblique, wide-angle, color, context views
- 60x180 deg
- >100x resolution of LRO LROC-NA



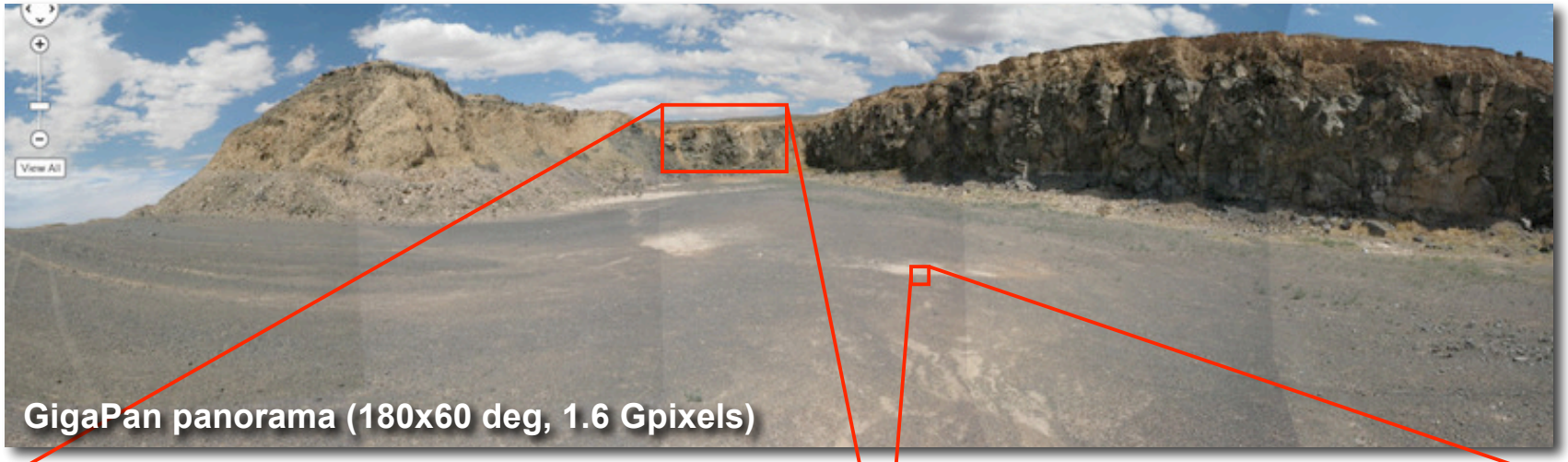
Microscopic Imager

- High-res, close-up, color, terrain views
- 72 micron / pixel
- >7,000x resolution of LRO LROC-NA

Orbital Data Examples

Digital Globe QuickBird (60 cm/pixel)

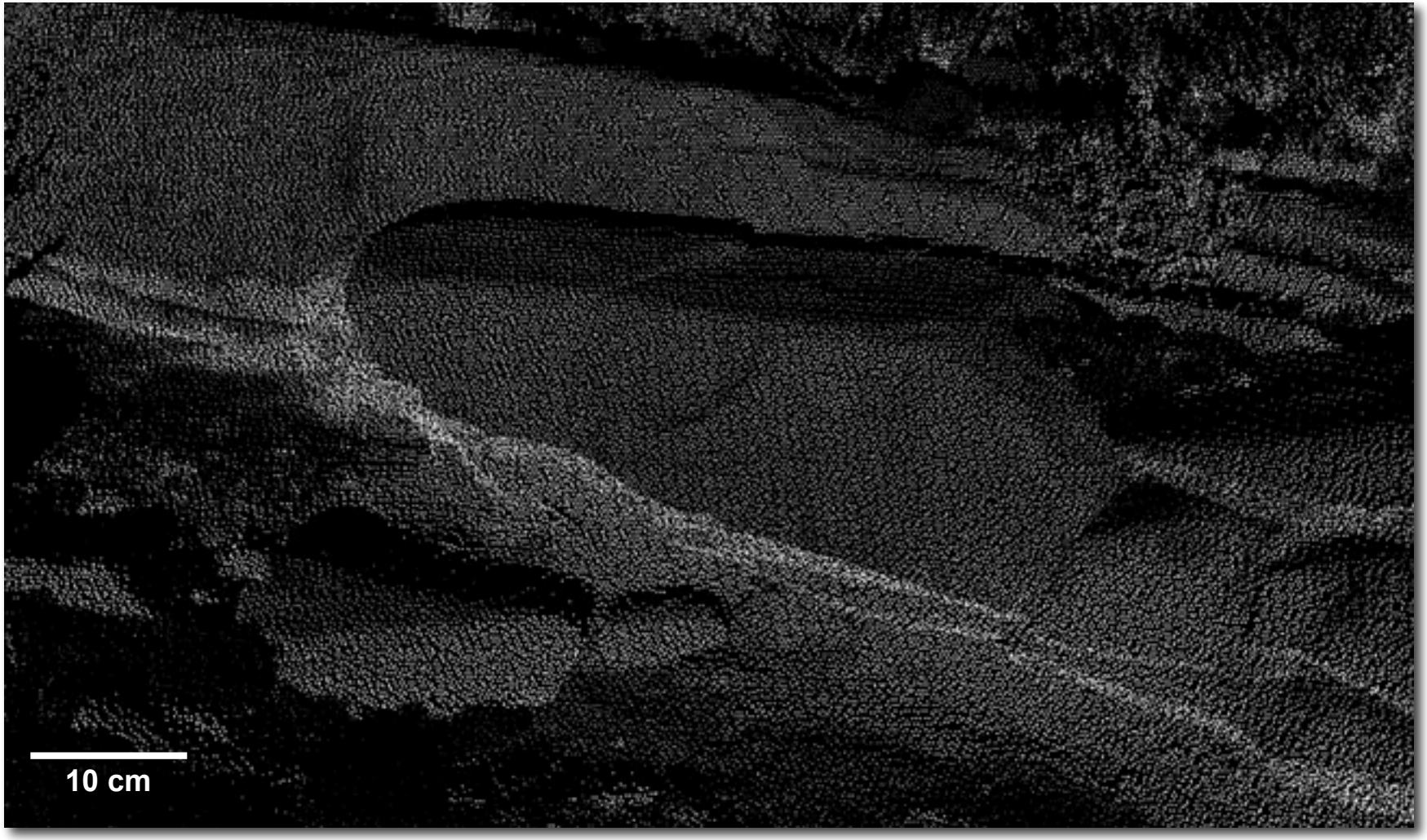
Surface Data Examples



GigaPan panorama close-up

Terrain image (55 microns / pixel)

Surface Data Examples

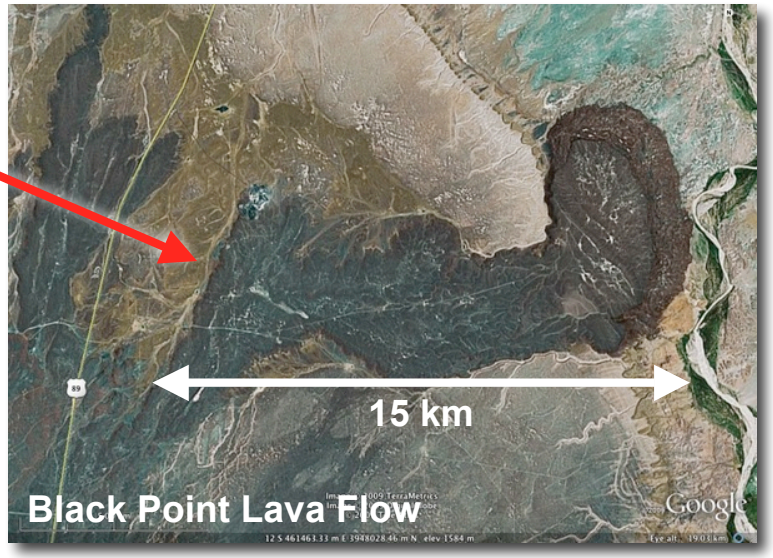


3D scanning LIDAR (250 m range, 3 mm depth resolution)

2009 Robotic Recon Experiment

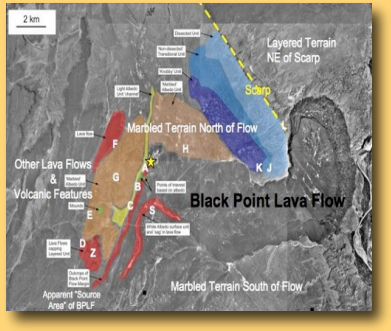
Black Point Lava Flow

- 50 km N of Flagstaff, AZ
- Analog of the “Straight Wall” (Mare Nubrium / Rupes Recta)
- Wide variety of surface features (outcrops & contact lines)



Approach

Pre-Recon



Mar 1 – June 1

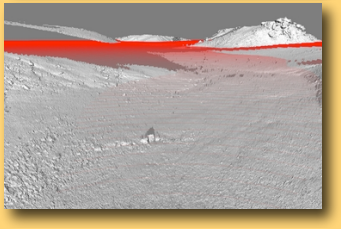
- Satellite images
- Geologic map

Robotic Recon Mission

June 14 – 26

- K10 at BPLF
- Ground control at NLSI

Pre-Crew



July 1 – Aug 15

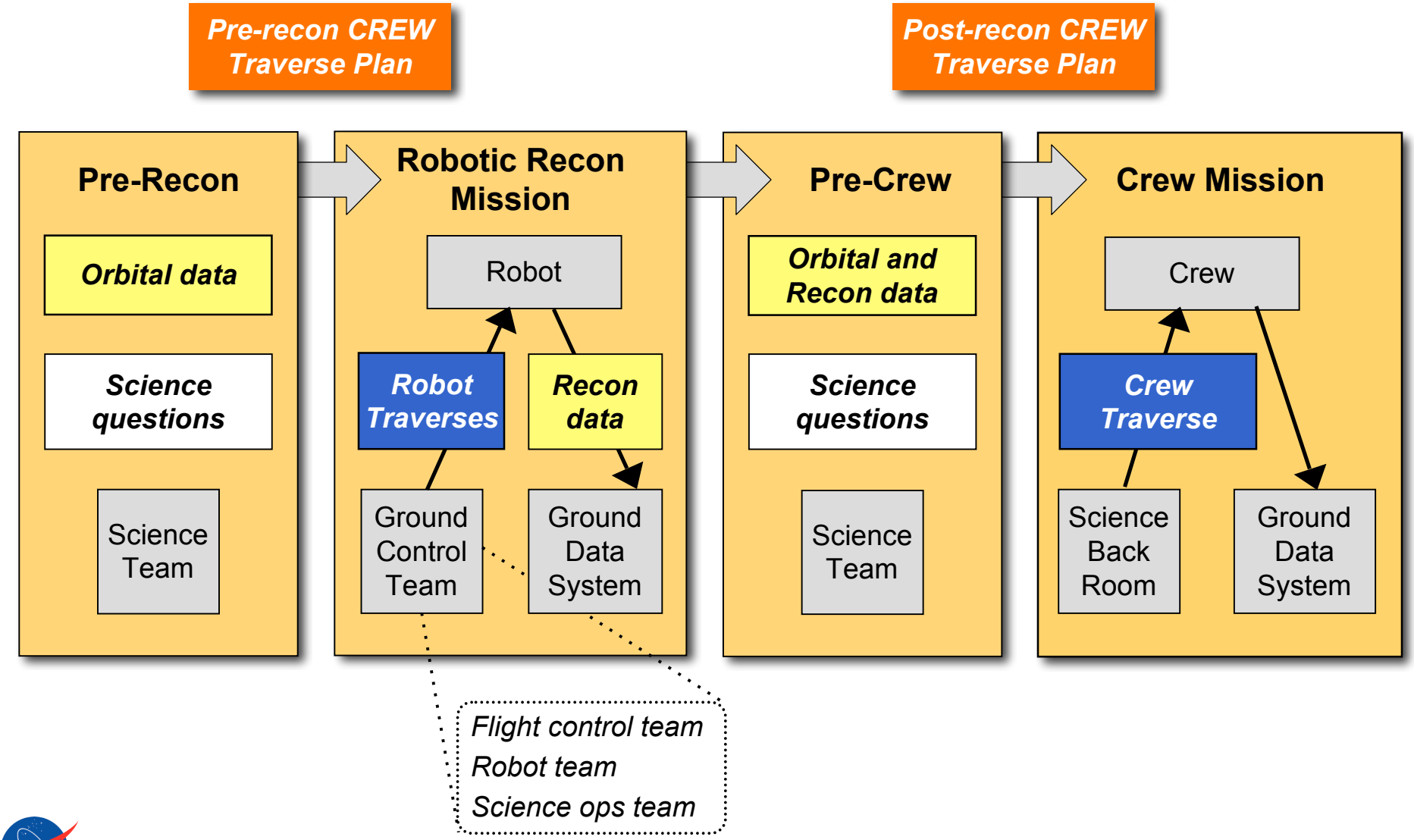
- Recon images
- Terrain models

Crew Mission

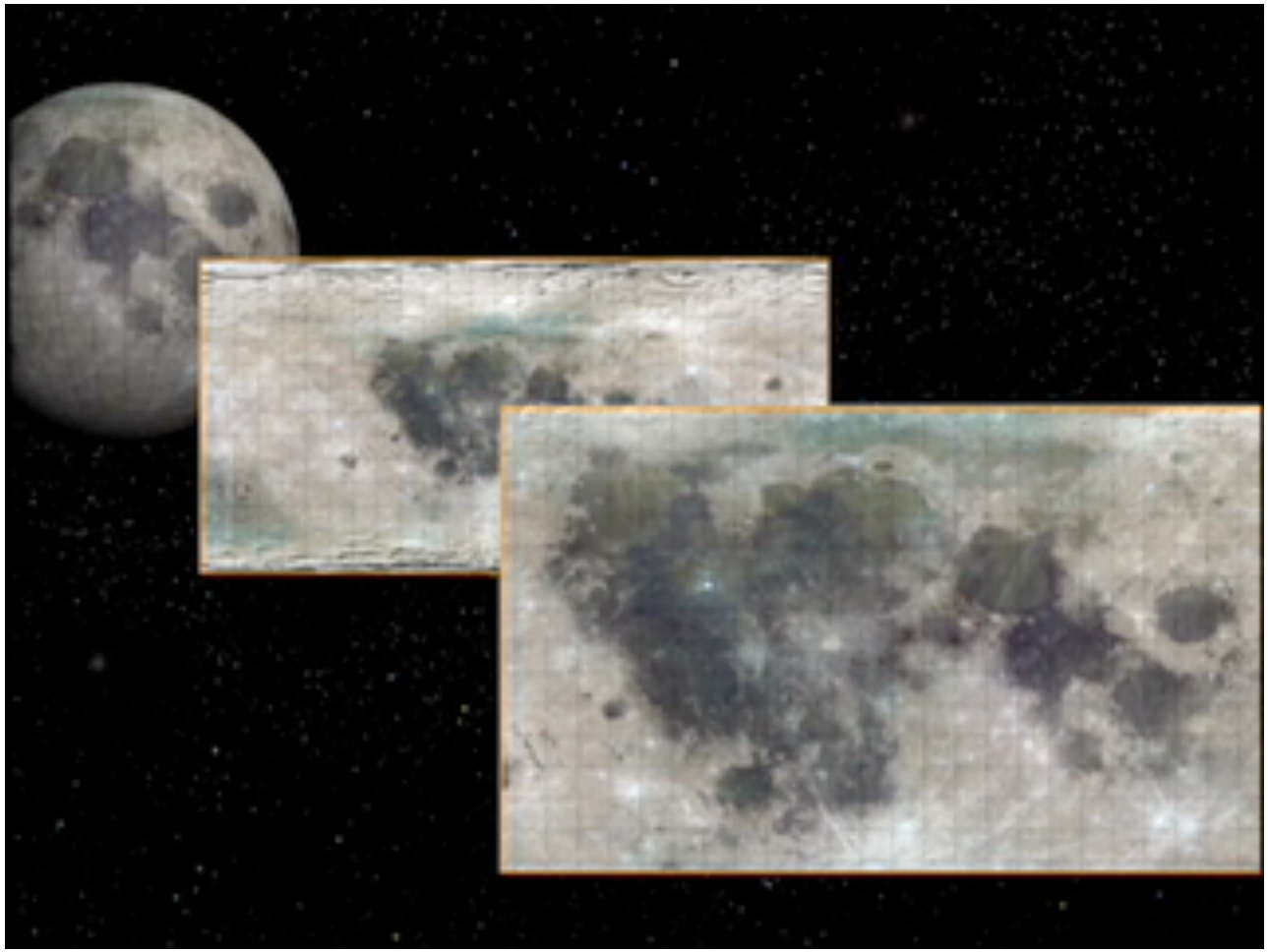
Aug 29 – Sep 3

- LER at BPLF
- Science backroom at BPLF

Approach


Pre-recon CREW Traverse Plan
Post-recon CREW Traverse Plan
Pre-Recon
Orbital data
Science questions
Science Team
Robotic Recon Mission
Robot
Robot Traverses
Recon data
Ground Control Team
Ground Data System
Pre-Crew
Orbital and Recon data
Science questions
Science Team
Crew Mission
Crew
Crew Traverse
Science Back Room
Ground Data System
Flight control team
Robot team
Science ops team

Robotic Recon Mission (June 2009)



Robotic Recon Mission Team

Experiment Team (at ARC)

- **PI / Sim Sup**: Terry Fong
- **Co-I / Science Integrity:** Pascal Lee
- **Assessment**: Andrew Abercromby, Estrellina Pacis, Debbie Schreckenghost

Flight Control Team (at ARC)

- **Directors**: Tim Kennedy (JSC-DO), Frank Jurgens (JSC-DX)
- **Controllers**: Mark Allan, Rob Landis, Eric Park, Melissa Rice, Hans Utz

Science Operations Team (at ARC)

- **Robot PI:** Kip Hodges
- **Traverse PI:** Jim Rice, David Kring
- **Scientists**: Mary Sue Bell, Jen Heldmann, Jose Hurtado, Art Snoke, Robert Stewart, Mike Wyatt, Aileen Yingst
- **Instrument leads**: Marwan Hussein, Ann Ollila, Nina Lanza, Jeff Tripp, Kelsey Young
- **Data Systems**: Matt Deans, Dave Lees, Trey Smith

K10 Robot Team (at BPLF)

- **Field Lead:** Linda Kobayashi
- **System Lead:** Maria Bualat
- **Engineers:** Xavier Bouyssousnouse, Susan Lee, Mike Lundy, Vinh To
- **Support:** John Porter, Armen Dibble

Communications Team (at BPLF)

- Jim Dumoulin (KSC), Mike Miller (KSC), Marc Seibert (KSC), Eugene Stoccardo (KSC)

Outreach Team (at ARC)

- Doris Daou, Estelle Dodson, Delia Santiago

Science Organizations

- **FEAT** (Field Exploration Analysis Team)
- **LEAG** (Lunar Exploration Analysis Team)
- **NLSI** (NASA Lunar Science Institute)
- **OSEWG** (Optimizing Science and Exploration Working Group)

Robotic Recon Mission Schedule

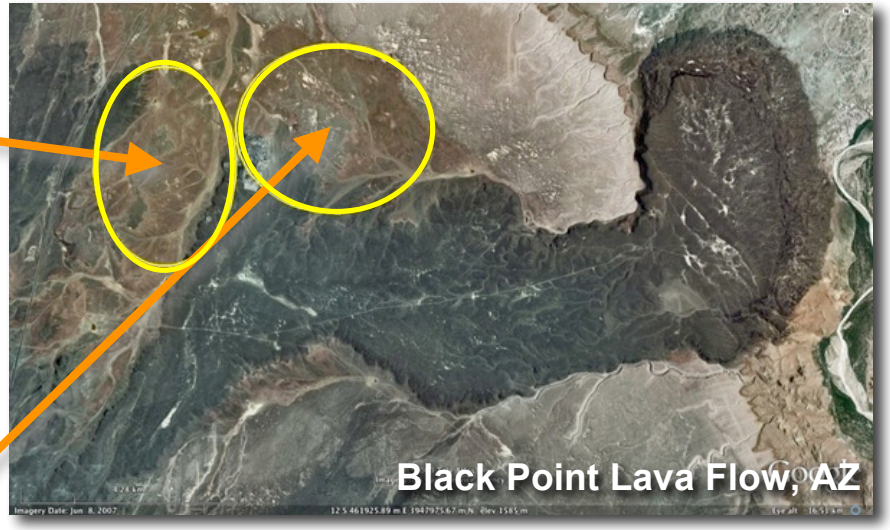
Setup (June 14 – 15)

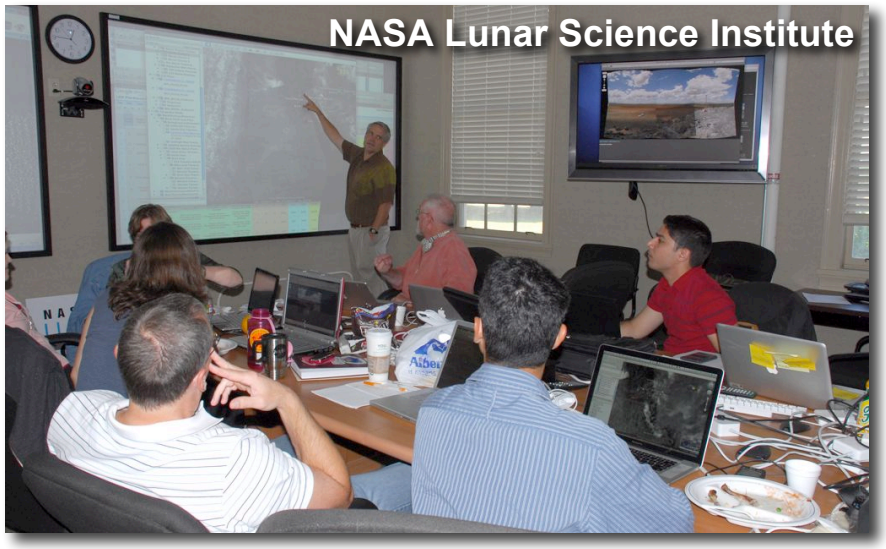
"West" Recon (June 16 – 20)

- 20-25 hr science ops (5 hr/day)
- Traverse PI: **Jim Rice**
- Kip Hodges, Pascal Lee, Art Snoke, Jose Hurtado, Ann Ollila, Nina Lanza

"North" Recon (June 22 – 26)

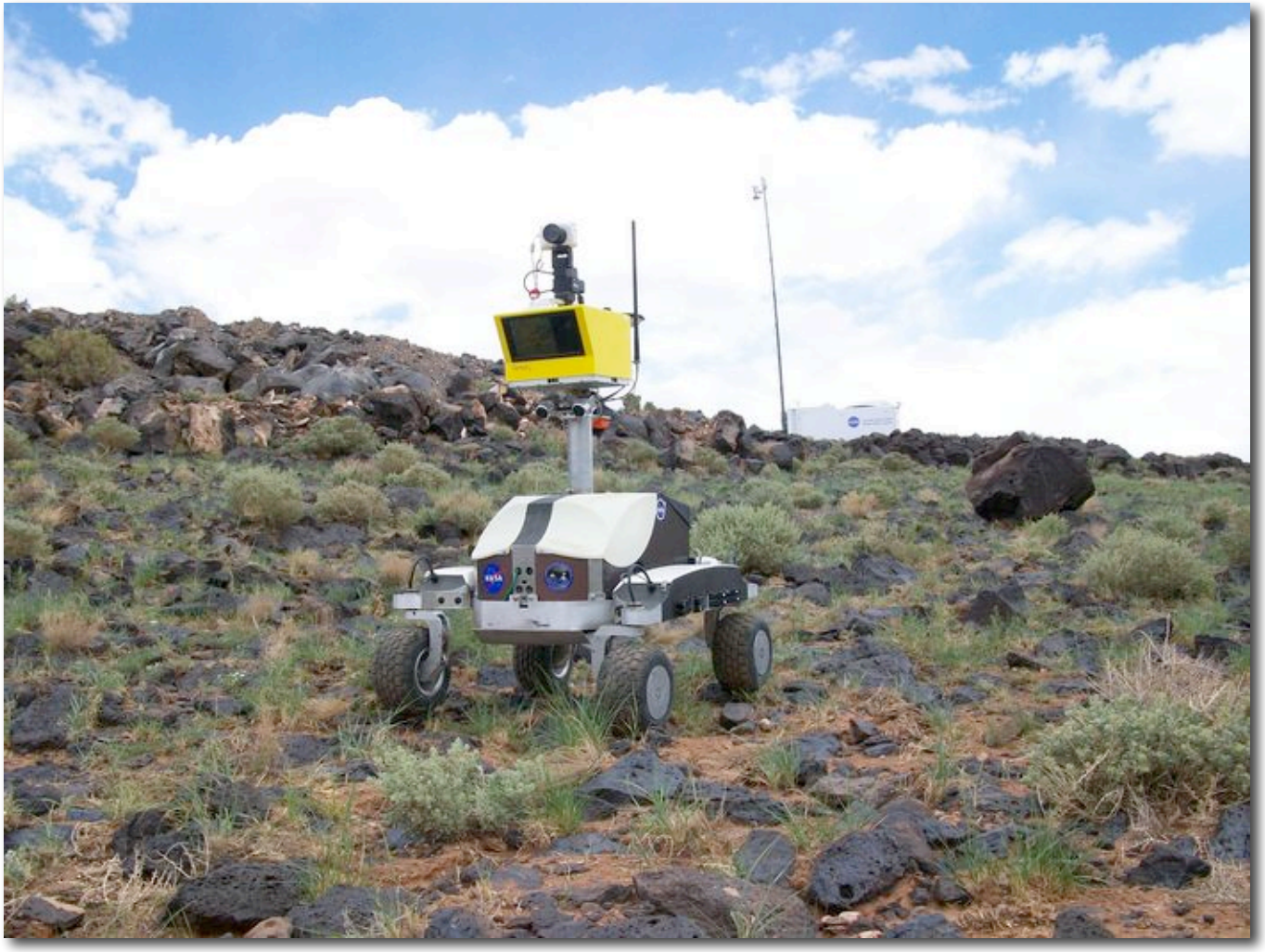
- 20-25 hr science ops (5 hr/day)
- Traverse PI: **David Kring**
- Aileen Yingst, Robert Stewart, Mike Wyatt, Mary Sue Bell, Kelsey Young



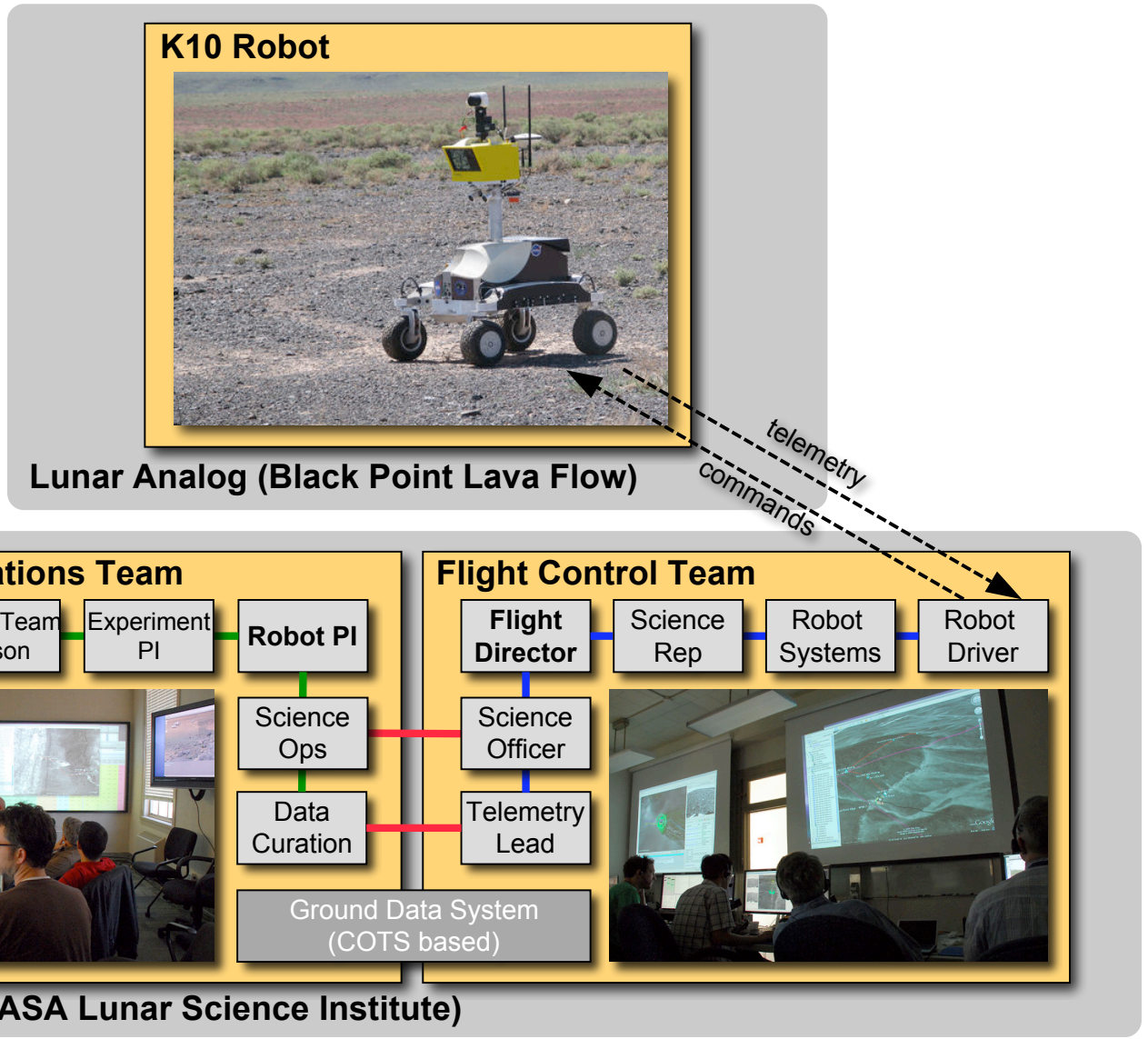


K10 at Black Point Lava Flow

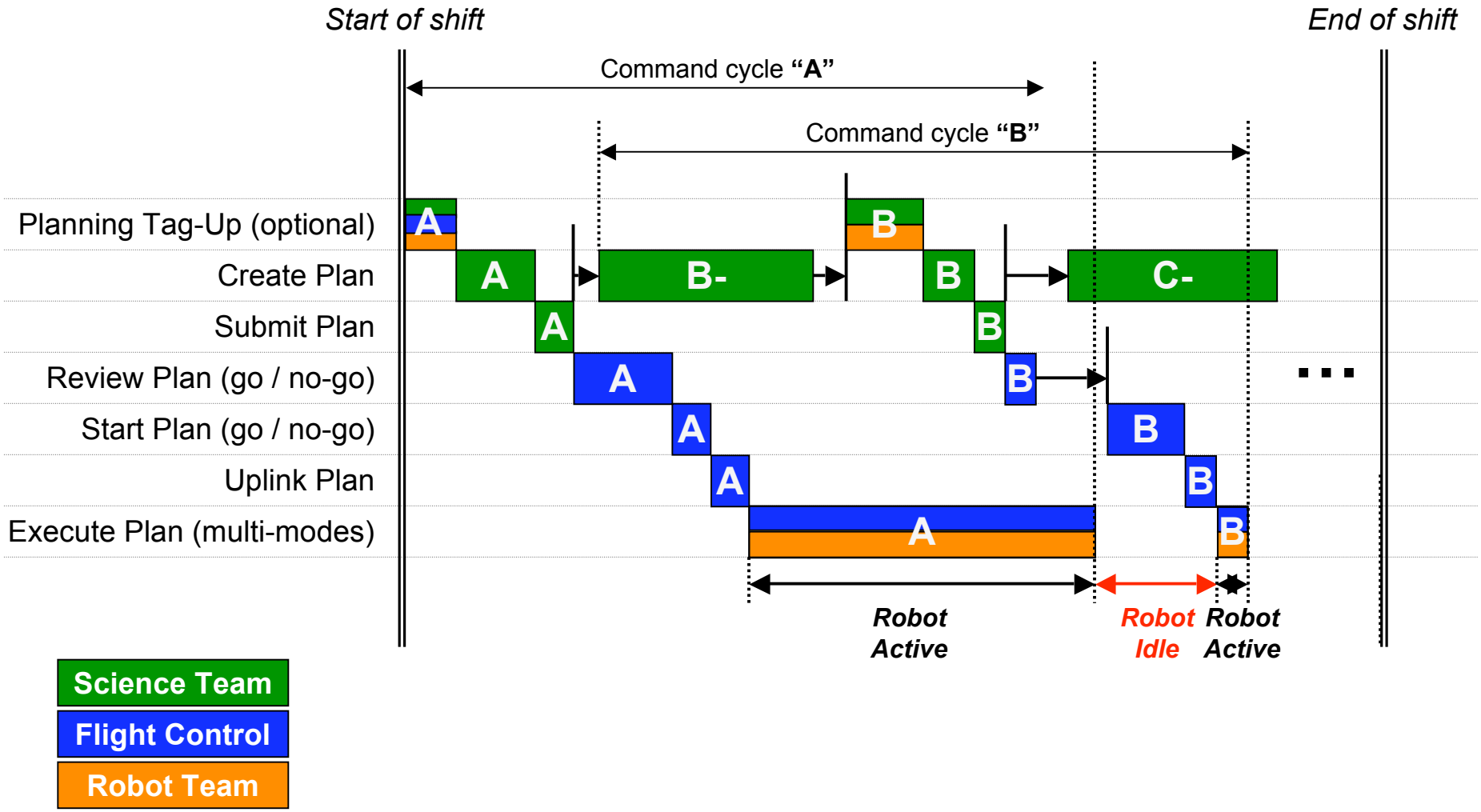
K10 at Black Point Lava Flow



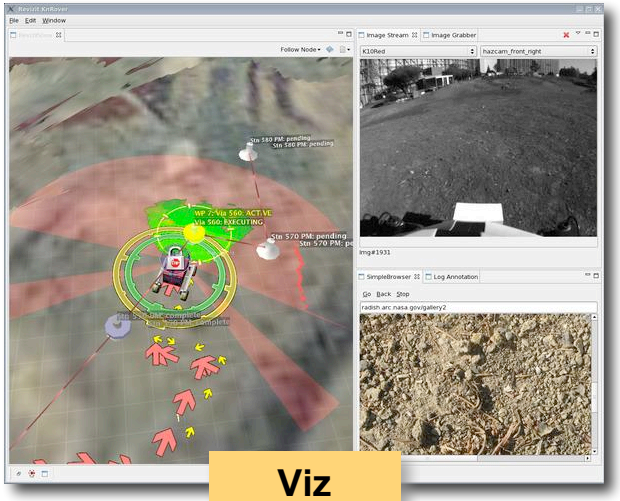
Ground Control at NLSI



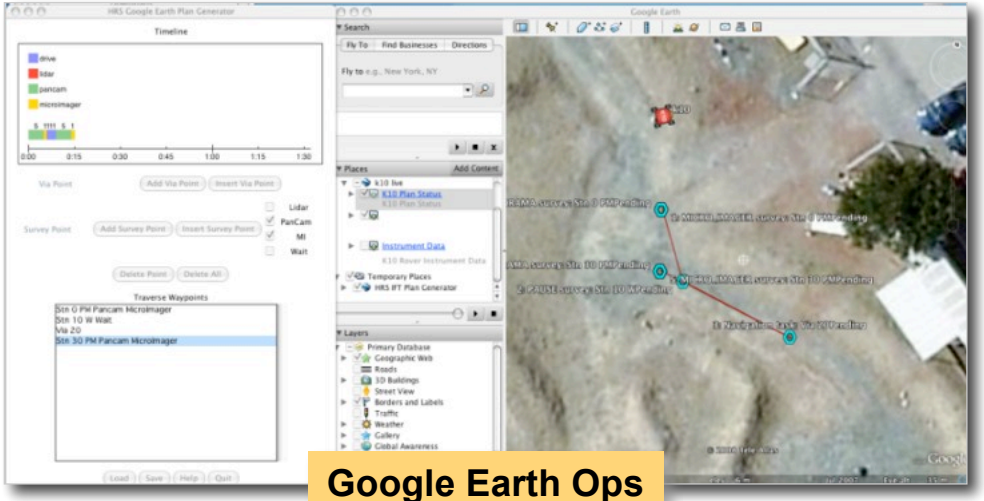
Tactical Ops Timeline



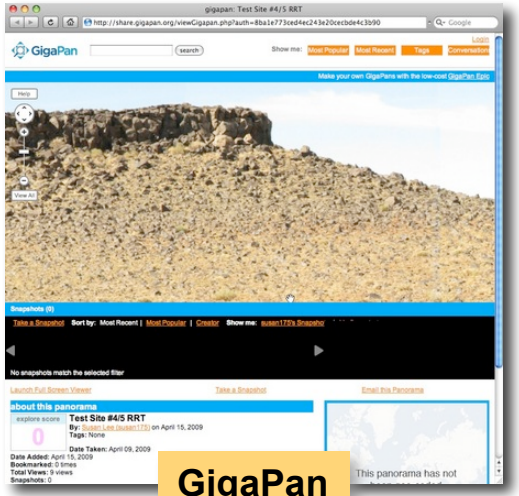
K10 Ground Data System



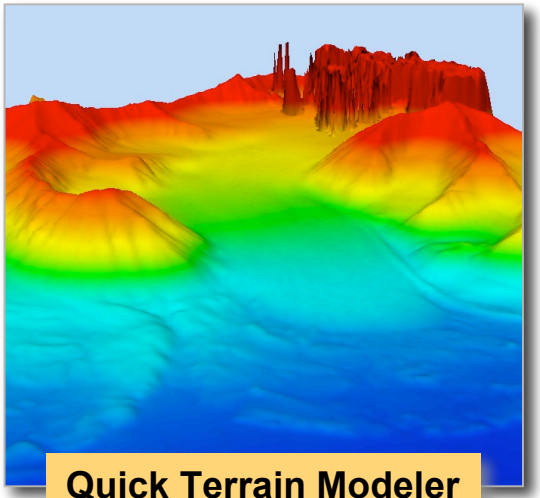
Viz



Google Earth Ops



GigaPan



Quick Terrain Modeler

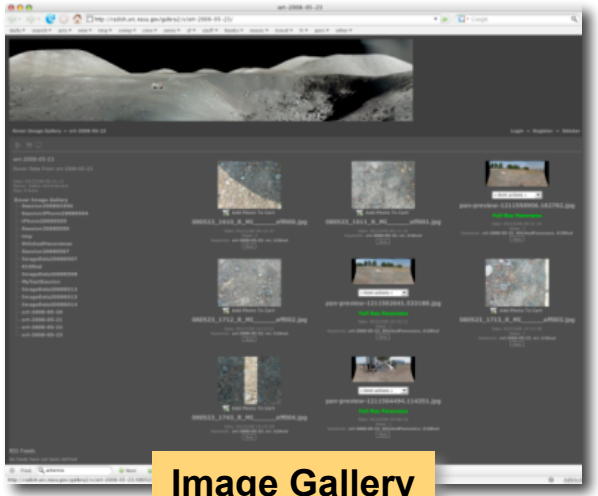
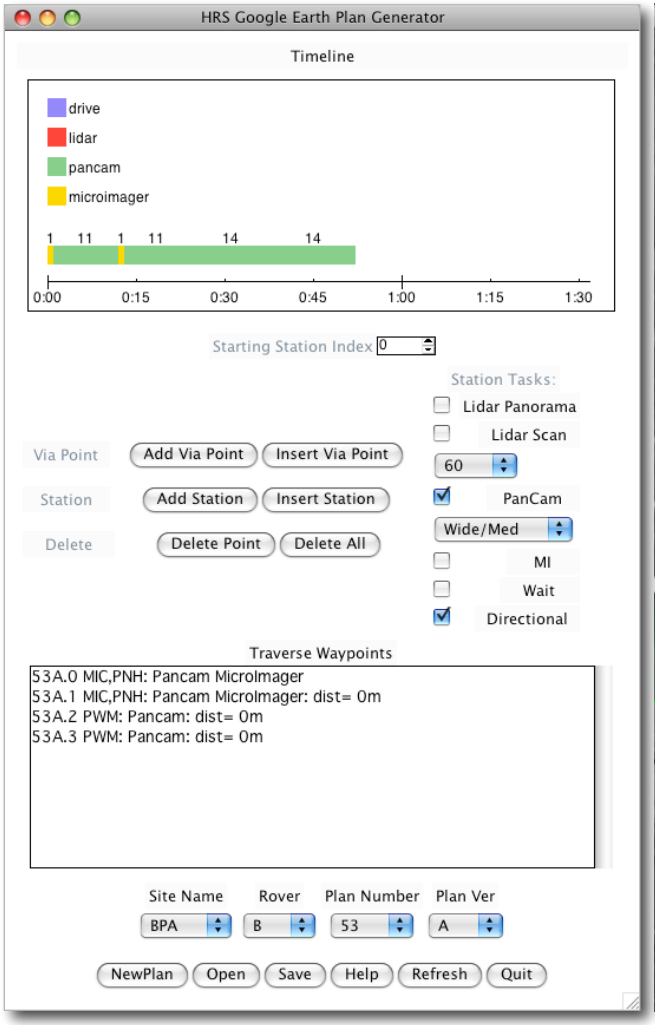
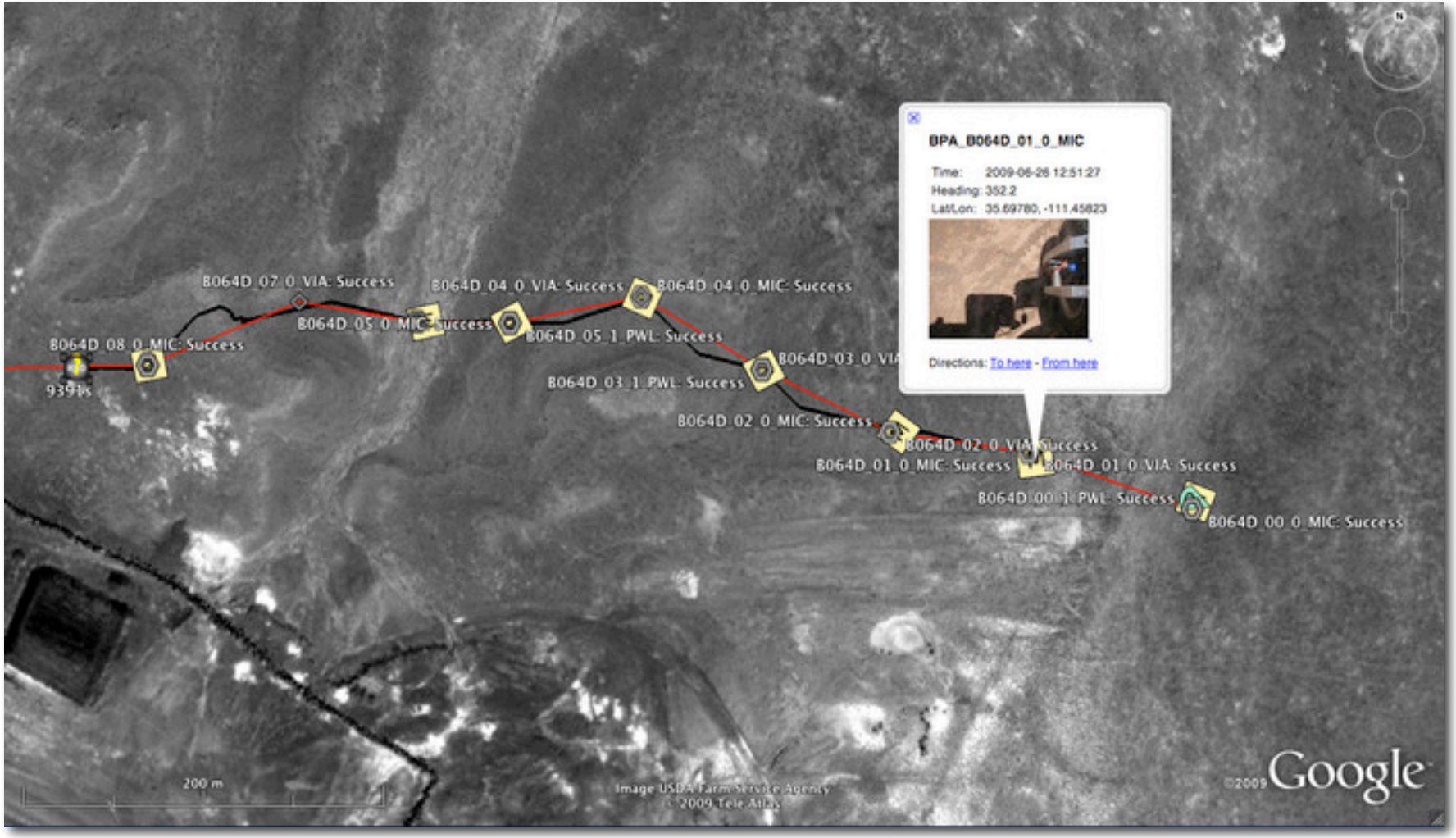


Image Gallery

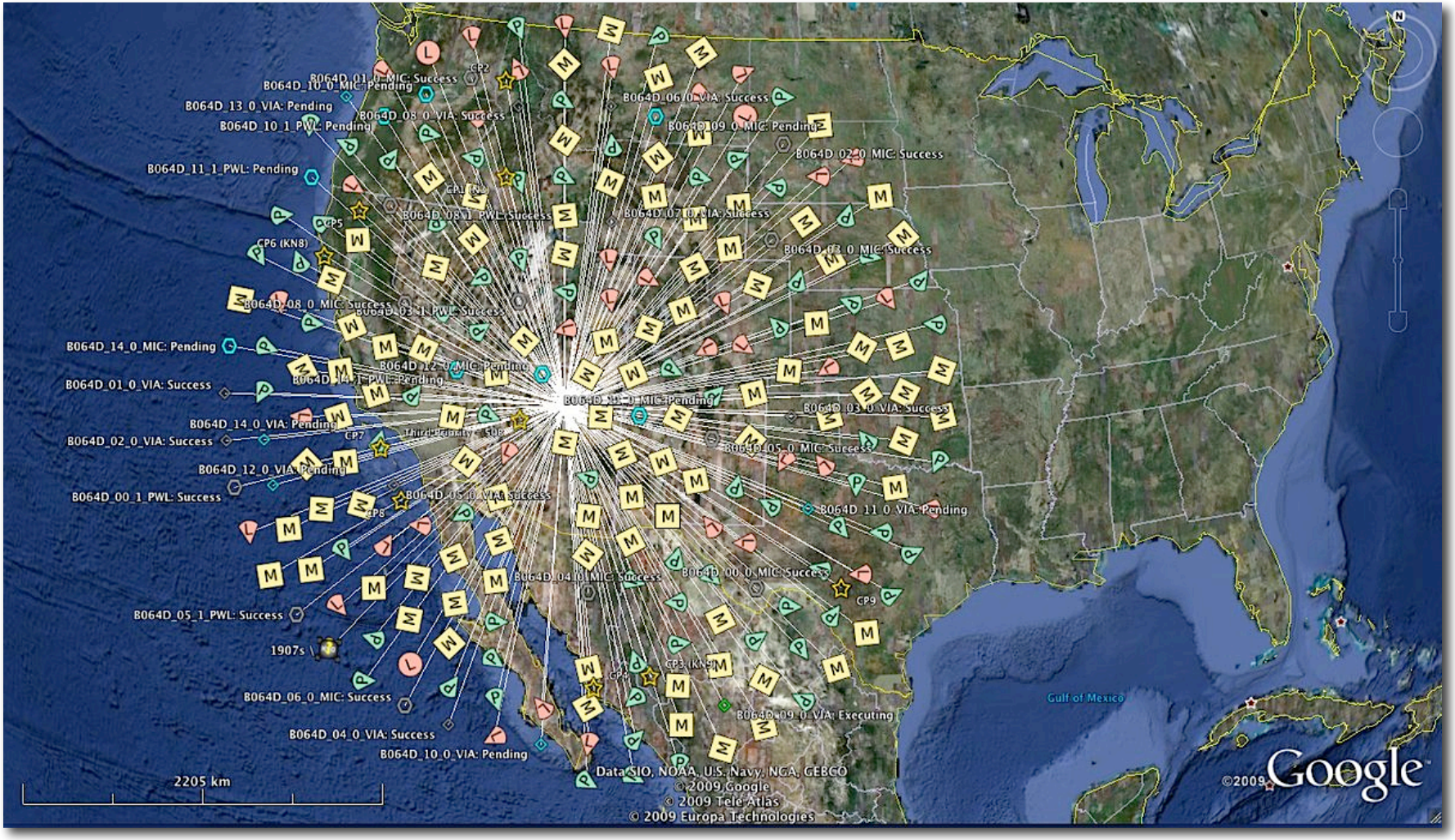
Google Earth Traverse Planning



Google Earth Monitoring & Data Viz



Collected Recon Data



8.5 GB data collected during 50 hr of robot operations
39 LIDAR scans, 75 GigaPan, 95 terrain images

Collected Recon Data

Lessons Learned (Preliminary)

Observation classes for robotic recon

- Precursor science: inform understanding → retire traverse objectives
- Logistics: inform operations → identify routes, hazards, etc.

Lunar robot science operations

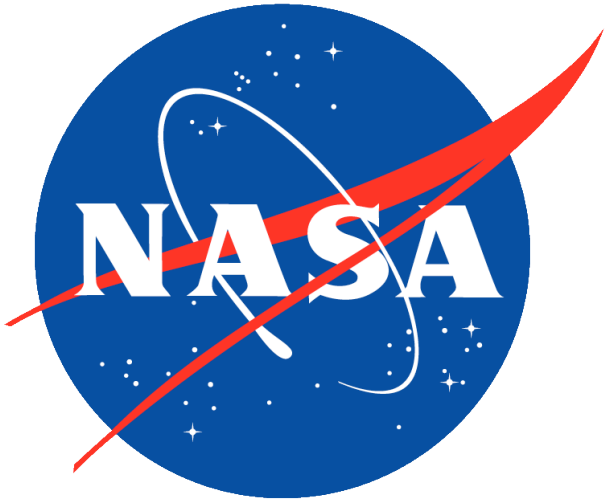
- Interactivity enables flexibility (can stop / discard / modify a plan)
- Real-time monitoring enables real-time science (like ROV ops)
- Rapid data acquisition + real-time operations = hectic
  ("Mars ops" seems sedate by comparison!)

Robotics for human exploration

- Fundamentally different than "robot as explorer" (e.g., MER)
- Critical to consider human-robot teaming (tasks, coordination, etc.)
- Potentially "game changing" for planetary exploration

Stay tuned… more to come !!!

Questions?



Intelligent Robotics Group
Intelligent Systems Division
NASA Ames Research Center

http://lunarscience.nasa.gov/roboticrecon

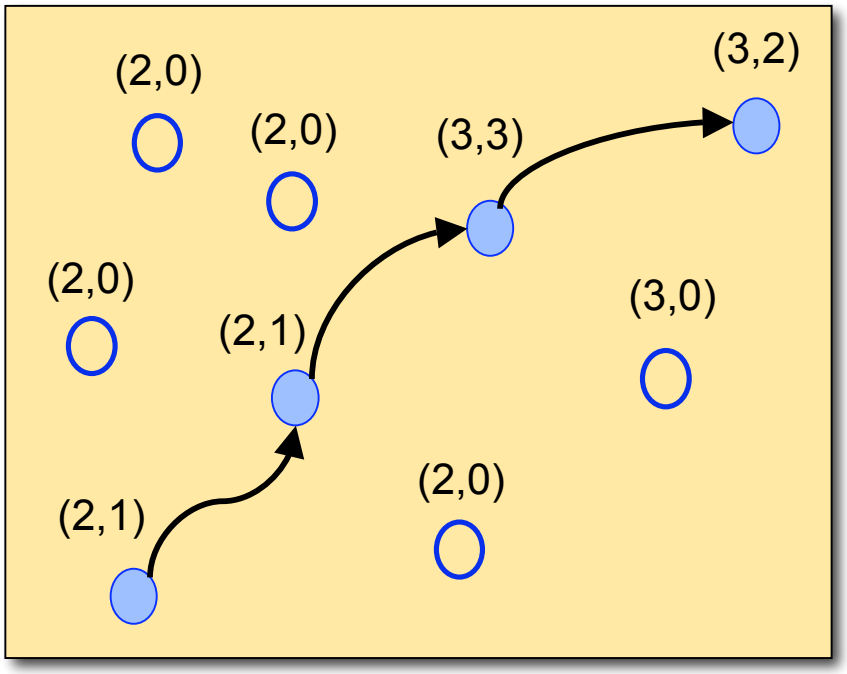
Methodology

Pre-recon

- Create two 1-day traverse plans
- Assign science merit to targets (including alternate targets)
- Select & prioritize targets for recon

Recon mission (K10 @ BPLF)

- Station-based recon
  - Real-time, interactive command cycle
- Accelerated timeline
  - Manually transport robot from target to target



(x, y) = (science merit, time at target)

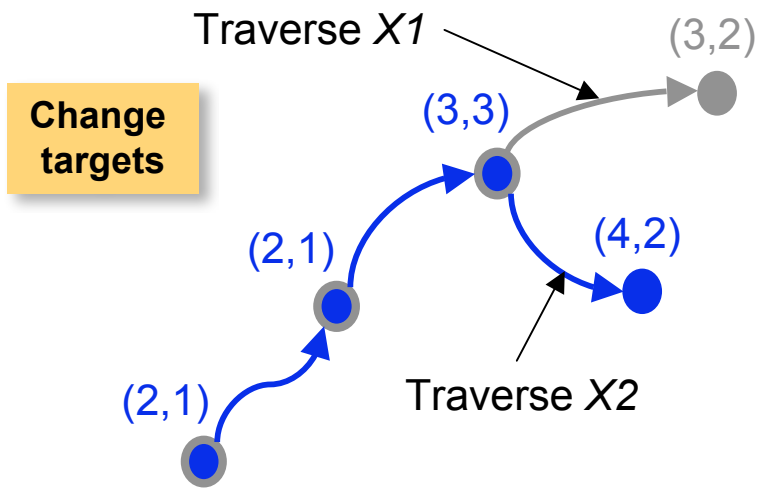
Methodology

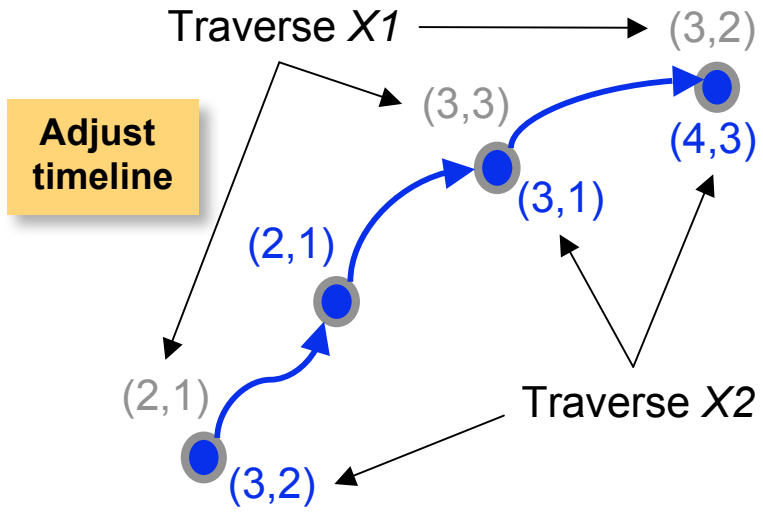
Pre-crew

- Revise traverse plans
  - Add/delete recon targets
  - Adjust plan timeline
- Re-evaluate science merit
- Prepare data for crew briefing

Crew mission (LER @ BPLF)

- Two crews
- Two traverses with each crew
- With recon data
  - Surface data available to science backroom and crew
- Without recon data
  - No surface data available





Impact on Traverse Planning

#	Hypothesis	Metric	Data Collection
1A	Robotic recon will improve the science merit of a traverse plan	• Pavillion Lakes Traverse Science Merit Rating	• Pre- & post-recon ratings by science team • Ground truth by field geologist
1B	Robotic recon will significantly change a traverse plan	• time at target • # of targets • qualitative change	• Estimated & actual times • Pre- & post-recon ratings by science team
1C	Robotic recon will reduce the uncertainty within a traverse plan	• certainty rating scale	• Pre- & post-recon ratings by science team

Impact on Crew Productivity

#	Hypothesis	Metric	Data Collection
2A	Robotic recon will improve the productivity of a traverse	• Weighted Sum of Completed Traverse Objectives	• Value of traverse objectives by science and ops teams • Ground truth by field geologist
2B	Robotic recon will increase the # of get-ahead tasks performed	• # of “get-ahead” tasks performed • Duration of “get-ahead” tasks	• Traverse actuals calculated from ops team reports
2C	Robotic recon will reduce time on-task	• EVA task completion times	• Traverse actuals calculated from ops team reports